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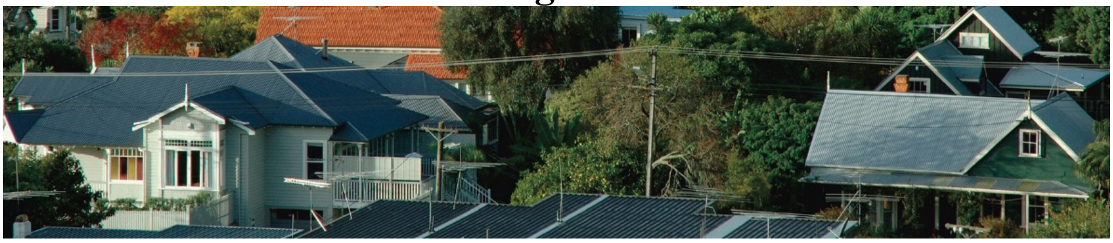

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Cost Benefits Of Housing Retrofits

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Summary

The housing stock is where a significant proportion of energy and water is consumed. About 34% of all electricity consumption is used in the home (Dang et al 2010). For water use about 48% of non-irrigation use is in the home (MED 2006). Efficiency measures in the home can have a significant effect on the use of these resources.

This project looks at the costs and benefits of various retrofits that can be used in the existing housing stock. The types of retrofit assessed include space conditioning measures such as insulation, double glazing, heating appliances, and solar panels. The cost-benefits of various heating appliances are evaluated. Water efficiency measures include low-flow shower heads, tap-flow reducers, wraps, dual flush toilets, and rainwater tanks. The net benefits are quantified for various measures by house type by climate zone.

The analysis was done in a spreadsheet model and the outputs are net present value, benefit-cost ratios, and payback periods. The main finding is that many common retrofit measures are cost effective in most parts of the country and that the payback period is quite short for many of these measures. Low cost measures such as cylinder and pipe wraps, draughtproofing and low-flow shower heads have good economic returns. The more expensive retrofits, ceiling and floor insulation are also cost effective in most situations.

Introduction

The costs and benefits of common types of energy and water saving retrofits were assessed for typical New Zealand houses. Space conditioning was modelled using ALF3.1 (Stoecklein, Bassett, 1999) and potential water savings were assessed from various studies (Heine, 2006), and others. This paper considers the 1940-60s housing group. This group was chosen because it is large, about a third of existing houses, is fairly homogeneous in design and size, and covers the period prior to mandatory insulation in new housing which began in the late 1970s.

Profile of 1940s-1960s houses

These houses typically have a single story, suspended timber floor, sheet metal or concrete tile roofs, and brick or timber weatherboard cladding. The vast majority has no wall insulation and are single glazed, but many have been retrofitted with ceiling insulation and floor insulation (with press-fit polystyrene). The ceiling retrofit is often to a minimal level (50 to 75 mm insulation). Flooring is mainly tongue and groove boards but some have particle board flooring. They tend to have average to leaky "air leakage".

Description of retrofit measures and packages

Four types of retrofit are considered in the financial model; water efficiency measures, insulation retrofit, retrofit glazing, and "other". The individual measures are listed in Table i. **Table i Cost details for measures and benefit: cost ratios**

Energy and water saving measures							
Measure	Initial	Replace		Benefit-cost ratio (1), (2)			
Water	cost $ (1)	Years	Comment	Auck	Well	Chch	Inverc
Solar water panels	7000	30	Assumes HWC needs replace, & plumbing.	1.1	1.1	1.1	1.2
HW heat pump	5500	20	Assume COP=2.8 & HWC needs replace.	1.0	1.0	0.9	1.0
Wetback	1000	40	$1,000 is marginal cost of plumbing to HWC.	5.1	5.1	4.7	5.2
Instantaneous gas	1750	20	One only. Save on standing losses.	2.5	2.5	0.4	0.4
HWC tempering value	300	20	Cost per Homesmart Renovations Plan Builder.	na			na
HWC Themostat	60	15	Save 10degC temp.	15.4	15.4	14.4	15.9
Dual flush cistern	120	15	Not many single flush anyway.	na			na
Rainwater tank (toilet, laundry only)	3000	40	Incl plumbing. 5,000 litre tank, toilet, laundry use.	0.4	0.3	0.3	0.3
Rainwater tank (garden only)	1000	20	1000 litre tank, outdoor use only.	0.3	0.2	0.2	0.2
HWC wraps	70	50	One cylinder only.	15.5	15.5	14.5	16.0
Pipe lagging	20	50	from one cylinder only.	18.1	18.1	16.9	18.7
Low flow shower	130	15	Two showers/day. 4 litre/min saving, 5 mins ea.	14.2	13.1	12.4	13.4
Flow restricter cold tap (bathroom)	30	20	1 tap only	1.9	1.4	1.4	1.4
Flow restricter cold tap (kitchen)	30	20	1 tap only	1.9	1.4	1.4	1.4
Insulation							
Ceiling nil, Add R4	2340	50+	$18 per sqm.	2.3	4.2	4.9	8.9
Ceiling 50mm, bring to R4	1820	50+	$14 per sqm	0.9	1.6	1.9	3.3
Ceiling 75mm or 100mm, bring to R4	1300	50+	$10 per sqm	0.7	1.3	1.6	2.8
Skillion relined (15% of area)	1365	50+	$70/sqm, 15% of ceiling area/ house on average	0.7	0.8	0.9	1.6
Wall add R2.8 replace Weatherbd/ FC	16744	50+	Allow chg stud height. R2.8 insul $165/sqm	0.2	0.4	0.5	0.9
Wall add R2.8 replace 50% Weatherbd	9555	50+	Allow chg stud height. R2.8 insul $105/sqm	0.4	0.8	0.9	1.6
Wall add R2.8 replace linings	6370	50+	Allow chg stud hgt/linings. R2.8 insul $70/sqm	0.6	1.1	1.3	2.3
Floor Timber Add Polystyrene	2080	50+	Polystyrene R2.0 or FG Cosyfloor R2.0 $16/sqm.	1.2	2.6	2.6	4.6
Floor Concrete add polystyrene perim	967	50+	$20/ lin m.	na			na
Draughtproofing (doors/ windows)	225	15	Assume 3 doors @ $15 ea,+6 windows @$30ea.	1.6	3.7	3.3	5.9
Windows							
Whole window replace Dble glaze	11440	40	Windows 22 to 25% of floor area, $380/sqm.	0.1	0.3	0.3	0.5
Replace glazing only, DG in alum	3718	30	$130/sqm DG, inserts, remove existing glass.	0.4	0.8	0.9	1.6
Replace glazing only, DG in rework timber	5577	30	Allow 1.5 factor for timber windows.	0.3	0.5	0.6	1.1
Secondary glazing panels	3432	20	Glazing in alum frame fitted behind existing glaze.	0.4	0.8	1.0	1.7
Curtains	1000	20	Assume major windows only, not service rooms.	0.5	1.0	1.2	2.0
Pelmets	120	20	Assume 6 windows required 12m x $10/m	na			na
Other (3)							
Ground polythene	520	40	Most post80's houses are slab.	2.9			2.9
Extractor fan for kitchen	250	15	Consumer Nov 2005. $250 ea incl duct.	1.9			1.9
Extractor fan for bathroom	250	15	Consumer Nov 2005. $250 ea incl duct.	1.3			1.3
Clothes dryer vent	70	15	Clothes dryer vent and ducting	4.5			4.5
Clothes line	150	15		0.0			0.0
Efficient light bulbs	30	8	5@60W/bulb saving,4hrs/day	20	20	19	21
Kitchen waste (worm farms v insinkerator)	120						

(1) Cost and BCR analysis are for the 1940s-60s mass houses. Other cohorts have similar values.
BCR = Discounted energy cost savings/(Insulation & water efficiency measures + heating appliance costs and discounted replacements)
(2) BCR assumes electricity heating, 0% takeback, 5% disct rate, 30 yr period, 1.6%pa energy price escalt
(3) " Other" benefits arise from reduced mould levels due to moisture control.

The model and its assumptions

Thermal modelling

Thermal envelope measures were modelled using ALF 3.1 and a typical 1940-60's house. 18^{o}C morning and evening whole house heating was used. Take-back in which energy savings are traded-off for increased temperatures was ignored in the Table and Figures 1 and 2. However take-back and the temperature levels are considered later in the paper.

Financial analysis method and assumptions

The present value method was used:
Present value PV = $\sum M/(1+r)^m + \sum H/(1+r)^h + C_1/(1+r) + C_2/(1+r)^2 + C_3/(1+r)^3 + \ldots + C_n/(1+r)^n$
Where:
M is the cost of the efficiency measure at year t=0 and allowing for replacement at year m.
H is the cost of the heating appliance at year t=0 and allowing for replacement at year h.
C_1, C_2, C_3, … + C_N are space heating energy or water supply costs in year 1, 2, 3 ….N.
r= discount rate.
N = period of analysis, years.
The base case parameters were:
30 years analysis period.
5% discount rate.

Energy prices were assumed to escalate at 1.6% pa above the general inflation rate. (Ministry of Economic Development, 2009).

The benefit: cost ratio is the present value of savings divided by the cost of the efficiency measure. A simple payback period was also calculated where Payback years = Initial cost of efficiency measure/Annual value of energy or water savings.

Electricity costs varied from 18c/kWh to 20c/kWh, depending on location. For heat pumps a coefficient of performance of 2.8 was used. The cost of water supply was assumed to be $1.2/cum in Auckland and $0.9/cum in the other locations, and have no change in real costs over time.

Payback period for individual measure

The payback period for common thermal envelope and water saving measures are shown in Figure 1 and Figure 2. These figures assume fuel prices at the normal electricity rates, except the last set of bars in Figure 1 assume a heat pump with no efficiency measures. Space heating is to 18°C morning and evening whole house.

Figure 1 Payback periods for envelop measures.

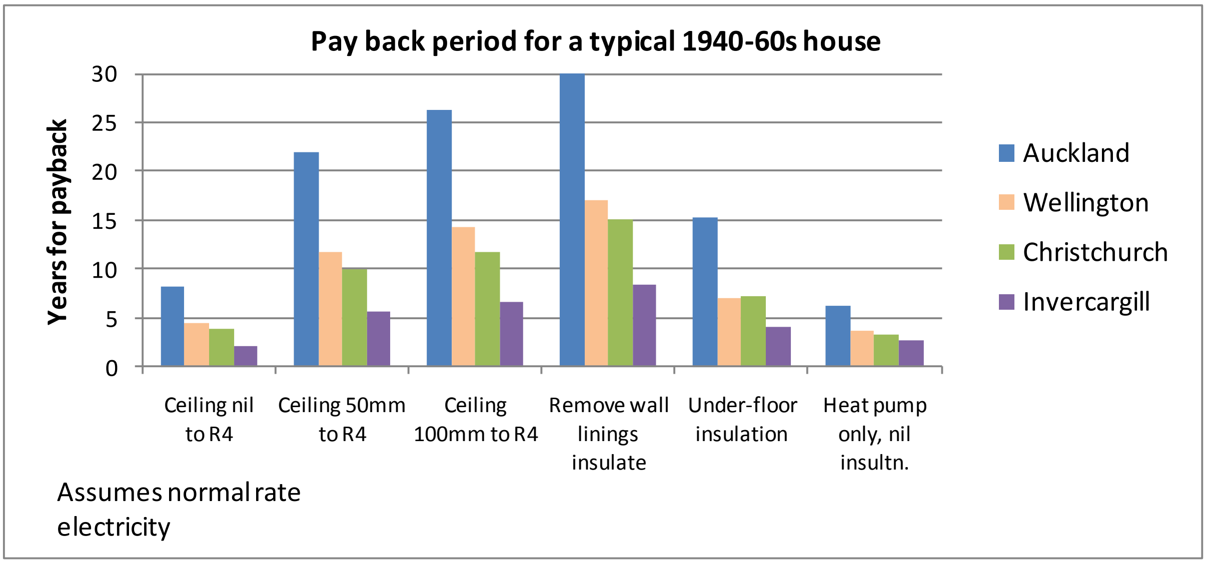
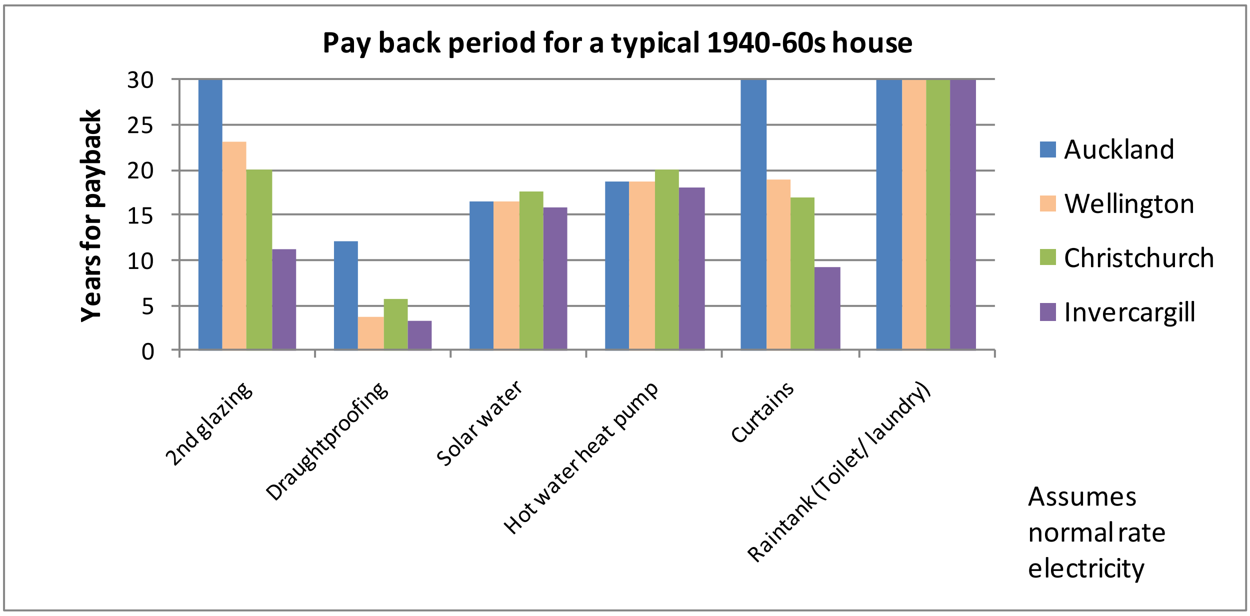


Figure 2 Payback periods for water saving and envelope measures

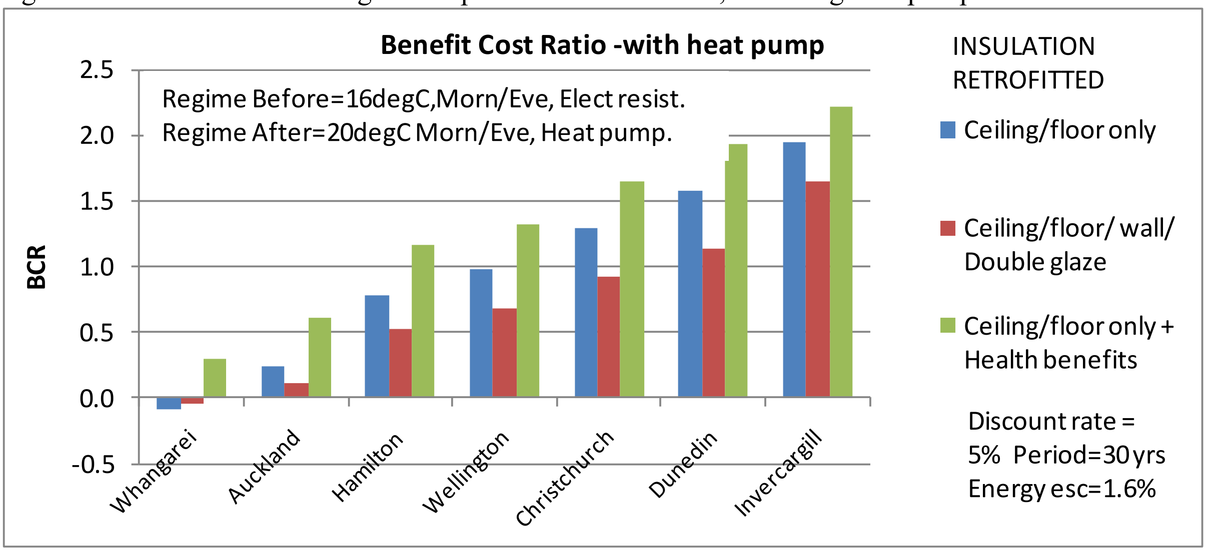


Improved comfort levels

Often the occupants chose to swap any energy savings after retrofit for an increase in comforts levels. Figure 3 shows the benefit: cost ratios (BCRs) with a rise in temperature from 16°C before retrofit to 20°C after retrofit, also assuming a new heat pump. Different levels of retrofit are shown for the different bars. The health benefits are included in the third set of bars, and these are discussed later.

A BCR of over 1.0 is required for the measure to be cost effective in the long-term (30 year analysis period).

Figure 3. Insulation BCRs – higher temperatures after retrofit, including heat pump retrofit



Often households are prepared to pay more for comfort when they know that the retrofit has reduced the amount of heat losses and they have an efficient heating system. In that case the question to ask is how much will it cost per year to achieve better comfort levels (rather than using BCRs as the metric).

Figures 5 and 6 show the additional annual costs when the temperature is raised from 16°C to 20°C Morning and evening heating only). The solid brown line is for electrical resistant heaters and existing minimal insulation (R1.5 ceiling only), and the blue lines are for ceiling insulation upgrade to R4.6, floor insulation and a heat pump appliance. The cost of the heating appliances is amortised over the period of analysis. The solid blue line allows for the government subsidy in the Warm Start programme, and the dotted blue line is without the subsidy.

Figure 4. Energy and appliance costs – Auckland

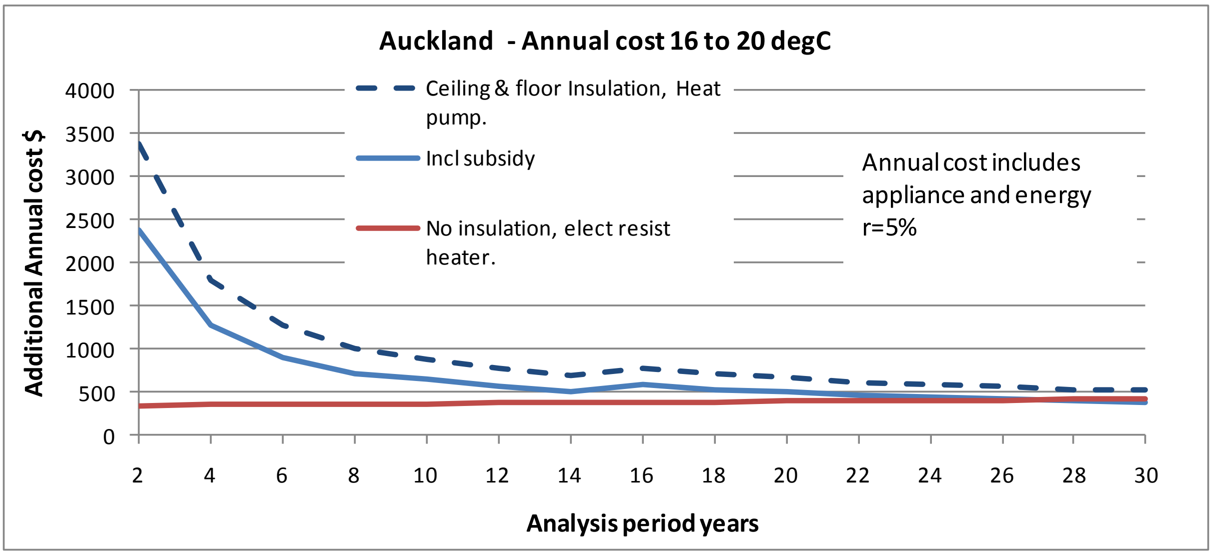
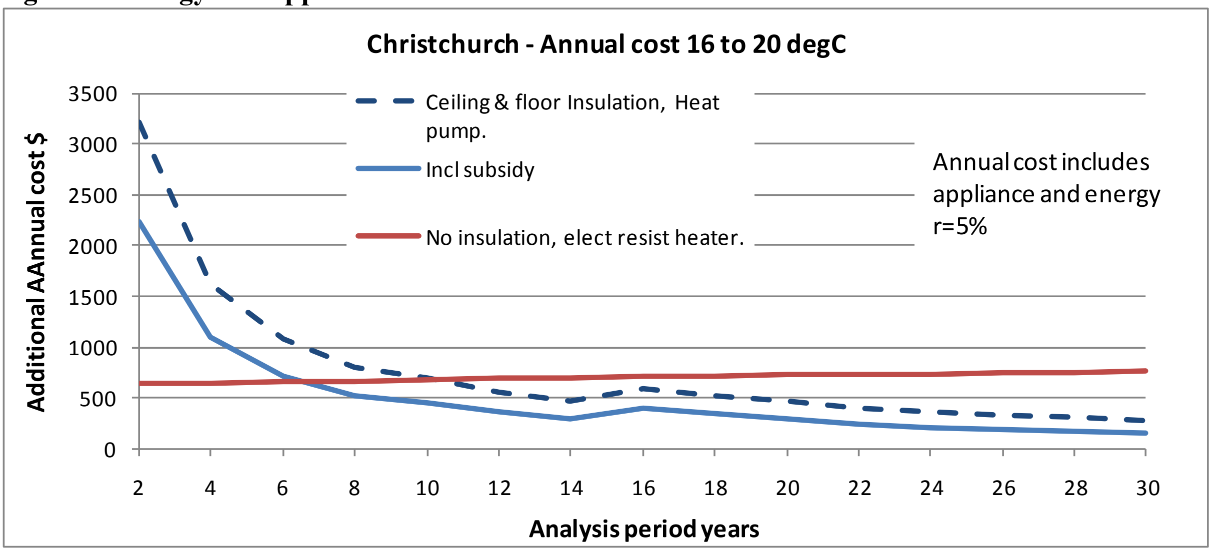


Figure 5. Energy and appliance costs – Christchurch



Note: In the above the Government Warm Up New Zealand: Heat Smart programme provides a 33% subsidy for the insulation cost, up to $1,300 (including GST), and another $500 (including GST) for a clean heating device e.g. a heat pump. The effect of the subsidy is the number of years to cross-over, as discussed below, are significantly reduced, making the programme quite attractive especially in the cooler regions.

Retrofit affordability

The ceiling/floor/heat pump retrofits shown in Figures 4 and 5 have an initial cost of about $6,600 after deducting the government subsidy. How affordable is this type of expenditure? The 2007 Household Expenditure Survey from Statistics New Zealand (SNZ) gives a breakdown of household expenditure by items. An average of $3,001 per year is spent on house maintenance, alterations and additions including DIY and using contractor services.

SNZ do not provide a breakdown of maintenance expenditure by deciles so this has been derived in Table 2. The assumption is maintenance expenditure is in proportion to household income.

Household decile groups from 2007 HES.

Deciles (1)	Under $17,600	$17,600 to $25,799	$25,800 to $33,399	$33,400 to $44,899	$44,900 to $55,799	$55,800 to $67,999	$68,000 to $80,899	$80,900 to $98,799	$98,800 to $131,299	$131,300 and over
Median income $ per yr	15,000	21,700	29,600	39,150	50,350	61,900	74,450	83,400	115,050	150,000
Ave Maintenance expend $ (2)	647	936	1,277	1,689	2,172	2,670	3,211	3,597	4,962	6,470
Yrs to save for retrofit (3)	20	14	10	8	6	5	4	4	3	2

(1) Income deciles $ thresholds are chosen to have equal numbers of households in each decile.
(2) Average property maintenance expenditure as derived by BRANZ, assuming expenditure is in proportion to income.
The average property maintenance expenditurefor all households is $ 3001 per year as per HES.
(3) Years to save for retrofit, assuming savings are 50% of previous maintenance expenditure.
The approximate cost of ceiling and floor insulation and a heat pump is $ 6600 after Govt subsidy.

Table ii. Ability of households to afford retrofit

Discussion

Table 1 provides benefit cost ratios for the various measures in the model. A ratio of 1 or more indicates the measure is cost effective. Hot water heat pumps, solar panels and double glazing retrofits are close to 1.0 ratio and are marginally cost effective, depending on the exact price of the measure.

Figure 1 and Figure 2 show the payback period. Generally the payback period needs to be about 18 years or less for there to be net financial benefits from a national perspective. Many owners will want a shorter payback, in line duration of ownership. The last census indicated only about 20% of the adult population stays at the same address longer than 14 years. This suggests the payback needs to be quite short (say 10 years or less) before owners are likely to consider retrofit for a cost viewpoint. The analysis in Figure 1 and 2 ignores any re-sale value improvements due to the retrofit, and other benefits such as reduced health costs.

One surprising result from Figure 1 is that the payback period using heat pumps alone is quite short. Replacing an electric resistant heater with a heat pump, and doing nothing else, has a better return to the owner than ceiling insulation.

Table1 and Figures 1 and 2 used 18°C morning and evening whole house heating. This is higher than current heating levels on average, according to the HEEP work (Isaacs et al, 2007), where average evening winter evening temperatures of about 16.8 °C were recorded in living rooms heated by electricity. The justification for using 18°C is that the housing stock needs to be upgraded to allow these temperatures to be maintained economically, and for health reasons (World health Organisation 1987).

It is known owners commonly take up the theoretical energy saving from efficiency measures in increased comfort. Figures 3 to 5 show the cost implications of this for space heating where the temperature is increased from 16°C to 20°C degrees. The energy savings from substituting a heat pump for an electric resistance heater are offset by the extra energy needed for the rise in temperature. Even so, in Wellington and cooler regions the net cost over the analysis period (30 years) is lower (with ceiling and floor insulation at 20°C) than the status quo of 16°C heating with a resistant heater and no added insulation. In warmer regions the net costs are negative, but that is the price people will often pay for higher comfort levels.

Non-energy benefits have not been included, and when health cost savings are included then Hamilton and cooler regions have a net benefit with ceiling and floor insulation (see Figure 3). Health cost savings are estimated at $215 per household per year for the case when temperatures are raised from 16°C to 20°C. This is based on work at the Wellington Medical School (Chapman et al 2004), adjusted for inflation and assuming similar health gains apply in raise temperatures from 16°C to 20°C as in the medical school study of smaller temperature rises but from a lower base (of about 14°C).

Figures 4 and 5 again look at increased comfort, but this time give the annual dollars required to achieve higher comfort. The retrofit and heat pump option has high annual costs for short analysis periods as the initial costs need to be recovered over a short time. As the analysis period increases these initial costs are spread over more years and the benefits of the lower heat pump energy cost becomes more important. For example, in Christchurch it cost an extra $600 per year to have increased comfort using the electrical resistance heater and no change in insulation (i.e. minimal ceiling insulation). If a heat pump and ceiling and floor insulation is installed then after about 10 years the annual costs are similar to the uninsulated resistant-heated house. I.e. an owner is better off after 10 years, and the cross-over occurs earlier at 6 years, allowing for the Government subsidy. Health cost savings have not been included and will reduce the payback time.

Table 2 examines affordability of retrofit measures. The current actual maintenance expenditure in the low income groups is probably over-estimated, and under-estimate it in the high income groups. This is because a high proportion of household spending in the lower deciles is on essentials such as food, clothing and transport, leaving little to be spent on maintenance. The converse occurs in high deciles, where the actual maintenance expenditure is likely to be higher than shown in the table.

If it is assumed that half the previous maintenance expenditure is used on retrofit then the table shows how many years of savings are required to purchase the retrofit package. Further assume that it would be unwise to divert half of maintenance expenditure for more than say six years. This then suggests the 40% of houses below $44,900 per year household income decile cannot afford the retrofit package unless expenditure on other goods and services is reduced.

Conclusions

There are a number of low cost efficiency measures in Table 1 that have good economic returns, including wraps, draught proofing, low flow shower heads, and efficient lights. These are the most cost effective measures to take with a limited budget. Next in priority is ceiling insulation, followed by floor insulation. Walls and windows are the remaining major component of a house requiring retrofit. Generally retrofit walls are cost effective in Christchurch and cooler regions, but double glazing retrofits are only cost effective in an Invercargill type climate. (This is for glazing heat loss only and not including draught-proofing which occurs with some secondary glazing systems.) These guidelines will vary a little depending on the heating regime and individual house characteristics.

The return on installing a heat pump is very good as the energy cost is reduced by about 65%. In terms of payback time it is quicker than installing ceiling insulation. However the message to give to owners is that other measures including ceiling and floor insulation are worth doing from a net cost position. Also, in combination with an efficient heater, such as a heat pump or solid fuel heater, the measures reduce energy use, increase comfort levels and improve health.

The large capital items are solar water panels and hot water heat pumps. At current prices the returns on these are marginal for an average house. However, assuming their price drops with increasing production and more experience in installation, they have the potential to be cost effective.

Acknowledgements

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